INFLUENCE OF GRAZING MANAGEMENT AND COPPER SUPPLEMENTATION ON THE GROWTH RATE OF HEREFORD CATTLE IN SOUTH-EASTERN QUEENSLAND

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SUMMARY

A 4-year study was made to evaluate the influence of grazing management and copper supplementation on the growth rate of Hereford cattle on predominantly *Paspalum dilatatum* pastures in south-eastern Queensland. Two systems were compared—one of set stocking and the other of rotational grazing through four paddocks, each for a period of seven days. The overall stocking rate was the same for both treatments. As this was a locality in which cattle consistently showed a low copper status in liver, half the animals in each grazing treatment were supplemented at regular intervals with intravenous copper sulphate.

In two of the four years the yield of pasture in the rotationally grazed paddocks was adequate for conservation in January/February. In 1957, approximately 56 tons of silage was conserved from the four 4-acre rotationally grazed paddocks, and fed back to animals in the rotational grazing treatment from June to December in that year. In 1959 approximately twice the amount of pasture was available. No conservation was practised as the object in this year was to compare the two grazing systems without the added variables of pasture harvesting and animal supplementation.

The data from this study support the following conclusions:—

(1) At a stocking intensity of one animal per acre in this environment the growth rate of Hereford cattle is not affected by the application of rotational grazing alone.

(2) Management by rotational grazing facilitates pasture conservation in years in which effective rainfall occurs in December/January.

(3) Feeding back of conserved pasture as a supplement in late winter/early spring increases animal productivity.

(4) In this locality a growth response to copper therapy in cattle can be expected in some seasons.

I. INTRODUCTION

Research on the relationship between grazing management and livestock production is in progress in many countries. Factors which have given impetus to this research are increased availability and decreased cost of chemical fertilizers, greater knowledge of and improvements in methods of pasture conservation, an increased appreciation of the economic importance of the maximum use of pasture in feeding for production, and recognition of the economic importance of optimum feeding for high-producing animals.

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Of the temperate pastures of New Zealand, McMeekan (1956) stated that the efficiency of conversion of high-producing grassland to animal products depends on grazing method, type of stock and stocking rate. He stated further that under the New Zealand conditions rate of stocking had a marked influence on efficiency of production on a per-acre basis, whereas even extreme differences in grazing methods resulted in only relatively small changes. McMeekan (1960), on the basis of work in progress in New Zealand, has drawn two conclusions. The first is that controlled grazing must be associated with high stocking rates to exploit fully the greater efficiency of the more intensive grazing method. The second is that increasing the stocking rate will not be accompanied by as large increases in output under set stocking as it will under controlled grazing.

Lassiter *et al.* (1956) reported the findings of 13-year studies in Kentucky to ascertain the effects of continuous and rotational grazing systems on the productivity of blue-grass pastures. The performance of dairy heifers indicated no differences between grazing systems. In Virginia, Blaser *et al.* (1959) compared a number of grazing systems on pastures composed of perennial grasses plus legumes. Their careful analysis of the data showed that any differences between systems were due to stocking rate. Output per animal under continuous grazing was often higher than for rotational grazing because of light stocking and herbage selection. In Texas, Riewe *et al.* (1959) found that continuous grazing on a perennial pasture consisting of predominantly Dallis grass and white clover resulted in more gain per steer and per acre than a system of rotational grazing.

In eastern Canada, Logan and Miles (1958) compared daily strip grazing with free range grazing for dairy cows during three pasture seasons. The pasture was a legume and perennial grass mixture, the predominant species being lucerne and orchard grass. A higher rate of supplementation was required to maintain milk production in cows on continuous grazing. From western Canada, Smoliak (1960) reported the findings from a 9-year study to compare the effects of rotational and continuous grazing on the growth rate of yearling heifers. Under the rotation system, defined as a two-field deferred-rotation, each paddock was ungrazed for three months during the summer grazing period in alternate years. Under these conditions ground cover tended to be better in the rotationally grazed paddocks but liveweight gains were greater with continuous grazing.

In studies on grazing management in the United Kingdom, Arnold and Holmes (1958) compared the influence of strip grazing and continuous grazing on the productivity of dairy cattle when stocking rate was held constant. The pasture species were ryegrass, timothy and white clover. Indices used were milk yield, milk composition and pasture utilization. Neither the yield nor the composition of milk was affected, but liveweight gain per cow was less under continuous grazing. This was attributed to gut fill and the authors suggested that this might mean that strip grazing could have been effected at a higher stocking rate without impairing milk yield. Campling, MacLusky, and Holmes (1958) determined production per animal and per acre for dairy cows under systems of grazing management which included strip grazing and continuous grazing on heavily fertilized grass swards. Stocking rate was varied subjectively to maintain the pasture in good condition. Grazing management had little influence on milk yield or composition but there was a 10 per cent. increase in cow-days per acre from the strip-grazed sward. This was attributed, at least in part, to differences in stocking rate.

In Australia, Freer (1959, 1960) studied the year-round utilization of temperate pastures by dairy cattle in Victoria. In the earlier experiment with the same overall stocking rate on irrigated pasture, strip grazing in twice-daily shifts and rotational grazing in 5–7-day shifts gave the same efficiency of pasture utilization. In the later experiment the same rotational grazing technique was used on both areas and stocking rate was evaluated. At increased stocking rates which over two seasons depressed total production per cow by 14 and 20 per cent., the animal production per acre was increased by 39 and 38 per cent. respectively. Body-weight gain was the component of animal production most affected by stocking rate. Milk production was relatively little affected although there was a significant depression in the solids content of the milk at the high stocking rate. Liveweight gains have been determined for Hereford cattle grazing native pastures in south-eastern Queensland (Anon. 1960, p.35). A number of grazing managements were compared, the overall stocking rate being constant. In 1958-59 there were no differences in animal productivity between the rotational and continuous grazing systems. In 1959-60 greater liveweight gain was recorded under the continuous grazing system.

A number of conclusions are evident from the available literature on grazing management. The first is that responses to any grazing system vary both between and within countries. The second is that the method of experimentation has a marked influence on the results obtained. The third is that, of the factors involved, stocking rate has the greatest influence on production per acre. The fourth is that there is little information available on grazing management of tropical or subtropical pastures.

The 4-year study (October 1956 to November 1960) reported in this paper was undertaken to compare two systems of management, continuous and rotational grazing, on subtropical pastures in south-eastern Queensland. The experiment was located on the predominantly *Paspalum dilatatum* pastures at the Animal Husbandry Research Farm at Rocklea, near Brisbane. Comparisons were based on the growth rate of Hereford cattle, the rate of stocking being the same for both treatments. The initial grazing intensity of one animal per acre was related to previous experience in this locality. When seasonal conditions permitted, excess pasture from the rotationally grazed paddocks was conserved as silage and subsequently fed back. As this locality was one in which grazing cattle consistently showed low liver-copper reserves (Sutherland 1956; Harvey *et al.* 1961; Riley *et al.* 1961), a copper supplementation treatment was superimposed on equal numbers of cattle from each grazing system.

II. MATERIALS AND METHODS

Experimental Area.—Thirty-two acres of grazing land at the Animal Husbandry Research Farm were selected for this study. Paspalum (*Paspalum dilatatum*) was the dominant pasture species. Green couch (*Cynodon dactylon*) was present in significant amounts and made a marked contribution to the diet of grazing cattle, particularly in winter months. Queensland blue couch (*Digitaria didactyla*) was also present in significant amounts during the winter months. White clover (*Trifolium repens*) varied with season from about 18 per cent. on a pasture population basis in the spring of favourable years to virtually zero population in summer. The area was subdivided to give two comparable 16-acre paddocks. One of these was further subdivided to give four comparable paddocks, each of 4 acres. Shade and water troughing were provided in the intact 16-acre paddock and in each of the 4-acre paddocks.

Experimental Animals.—Hereford heifers were used throughout the study. The stocking rate for each grazing system was one animal per acre except from March to October 1958, when adverse seasonal conditions necessitated a reduction to one animal per 1.6 acres for each system. At the commencement of the experiment the 32 heifers, selected from the Rocklea herd, were from Hereford cows mated to the one Hereford bull. Of these heifers, 20 were approximately 9 months of age and 12 approximately 18 months. In October 1958 the older animals were replaced by Hereford heifers aged about 9 months. A similar procedure was followed in November 1959, the older animals being replaced by Hereford heifers aged about 9 months.

All experimental animals had negative serological tests for contagious abortion, pleuropneumonia and *Leptospira pomona* throughout the experimental period. Initially and throughout the experiment low cattle tick (*Boophilus microplus*) populations were ensured by regular dipping in a vat containing a DDT proprietary. All cattle were routinely inoculated at intervals of approximately three months with blood containing the protozoans *Babesia bigemina* and *B. argentina* as a precaution against isolated cases of tick fever under the experimental conditions of low tick infestation.

Copper Therapy.—An equal number of animals in each grazing system were kept copper-adequate by 3-monthly intravenous injections of copper sulphate. Initially the dose rate was 30–60 mg Cu, depending on body-weight, and repeated on three occasions at 4-day intervals, using $0 \cdot 5$ per cent. aqueous solution of copper sulphate. In the second year of the study the dose rate was increased to 60–120 mg Cu, depending on body-weight, and repeated as previously at 4-day intervals, using $0 \cdot 125$ per cent. aqueous solution of copper sulphate injected by means of a flutter valve.

Body-weight.—Cattle were weighed on a cattle-weighing scale with an accuracy of ± 1 lb. On each occasion animals were yarded and weighed at approximately the same time of day.

Grazing Behaviour.—At intervals throughout the study, observations were made on grazing behaviour. On each occasion the test period was 24 hr, observations being recorded at 10-min intervals. The recorder was located in a tower 20 ft above ground level, additional aids being 7 x 50 binoculars and a 12V spotlight. Behaviour was defined as grazing, lying down or loafing, the last being neither grazing nor lying down.

Pasture Management.—The rotationally grazed paddocks were grazed for one week and spelled for three weeks. Within 24 hr of being vacated, each paddock was harrowed with the object of spreading faeces voided by cattle during the previous week.

In February 1957 the rotationally grazed paddocks were mown with a cutter-bar type harvester and 56 tons, equivalent to 14 tons dry matter, were conserved as silage. This was fed back as a supplement to the rotationally grazed group at the rate of 30 lb per head per day from June to December 1957. For reasons related either to the experimental programme or to adverse seasons, no silage was conserved in the succeeding three years of the experiment.

Animal Sampling.—Liver samples for copper analysis were obtained by the biopsy technique of Loosmore and Allcroft (1951) with the instruments described by Dick (1952). Blood samples were obtained with stainless-steel needles from the jugular vein on the same day as liver sampling.

Pasture Sampling.—Pasture yields were obtained by sampling from quadrat areas, 100 in. x 36 in., within moveable wooden exclosures each 10 ft x 10 ft. Cuts were made with an Allen-Oxford autoscythe, set to mow at a constant height of approximately 2 in. above ground level. Four exclosures were located in the rotationally grazed area and 10 in the continuously grazed paddock. Exclosures were moved after each yield measurement except during the last year of this study.

Botanical composition was determined by line transect counts taken at random distribution along six traverse lines in each paddock. In each 4-acre rotationally grazed paddock 4 x 100-in. transects per traverse gave a mean count based on 2,400 in. In the 16-acre continuously grazed paddock, 8 x 100-in. transects per traverse gave a mean count based on 4,800 in.

Chemical analyses were restricted to the main pasture species, paspalum and green couch, plus white clover when available in sufficient quantity. Samples were collected from within the exclosure, using stainless-steel scissors, and were hand-sorted to ensure single species. Samples were collected at approximately monthly intervals, the intervals extending to three months when growth was limited. All analytical samples represented regrowth from the previous sampling period.

Analytical Method.—Copper analyses on blood, liver and pasture were by the method of Clare, Cunningham, and Perrin (1945). Blood inorganic phosphate, haemoglobin and packed cell volume were determined by the methods of Moir (1954), Donaldson *et al.* (1951) and Wintrobe (1947) respectively. The official methods of the Association of Agricultural Chemists (1955) were used in the proximate analysis of pasture. Molybdenum in pasture was by the method of Dick and Bingley (1951). Inorganic sulphate was determined by a modification of the benzidine sulphate method of Bingley and Dick (personal communication 1953). Silage quality tests were by the methods of Watson and Ferguson (1937).

III. EXPERIMENTAL

At the commencement of this study in October 1956 the 32 Hereford heifers were allotted to four groups by stratified allocation on the basis of body-weight and age. Groups were assigned at random to the following treatments:—

Group	No. of Animals	Treatment
S	8	Set-stocked at 1 animal per acre.
Sc	8	Set-stocked as for S plus 3-monthly intravenous copper therapy.
R	8	Rotationally grazed at 7-day intervals in each of four paddocks; overall stocking rate at 1 animal per acre.
Rc	8	Rotationally grazed as for R plus 3-monthly intravenous copper therapy.

From March to October 1958 the number of animals in each treatment was reduced to five. In October 1958 and November 1959 replacement heifers were assigned at random to each treatment after stratified allocation on a body-weight basis into four groups. From October 1958 until the conclusion of the experiment in September 1960 the number of animals per treatment was maintained at eight to give a stocking rate equivalent to one animal per acre.

Data obtained on all experimental cattle during this 4-year study included body-weight at 2-weekly intervals; blood analyses for copper, inorganic phosphate, haemoglobin and packed cell volume at 3-monthly intervals; liver analyses for copper at 3-monthly intervals; and grazing behaviour in January, April, July and November in 1957, March and June in 1958 and 1959 and April and May in 1960.

Data obtained on pasture included botanical composition by line transects initially in October 1956 and again in the adverse winter of 1960 just prior to the conclusion of the study; yield by quadrat measurement of regrowth at intervals when sufficient pasture was available; and chemical composition by the analysis of individual pasture species.

Pasture from the rotationally grazed paddocks was conserved as silage in February 1957. This was fed back to animals in the rotational grazing treatment at the rate of 30 lb (7·5 lb dry matter) per head per day from

May 30 to November 6, 1957, and again from November 25 to December 28, 1957. Adverse seasonal conditions prevented pasture conservation in January and February 1958. Although adequate pasture was available, no conservation was practised in January 1959, the objective in this year being to compare the two grazing systems without the additional variables of pasture harvesting and supplementary feeding. Pasture growth was satisfactory in December 1959, but in the absence of expected December/January rain both the quantity and the quality of the pasture were inadequate to warrant making silage in January/ February 1960.

IV. RESULTS

Body-weight.—The mean changes in body-weight of cattle in each group are shown in Figure 1. Linear growth rates and standard errors of group means are recorded in Table 1. Spot analyses of body-weights were made at intervals just prior to changes in experimental animals and are shown in Table 2.

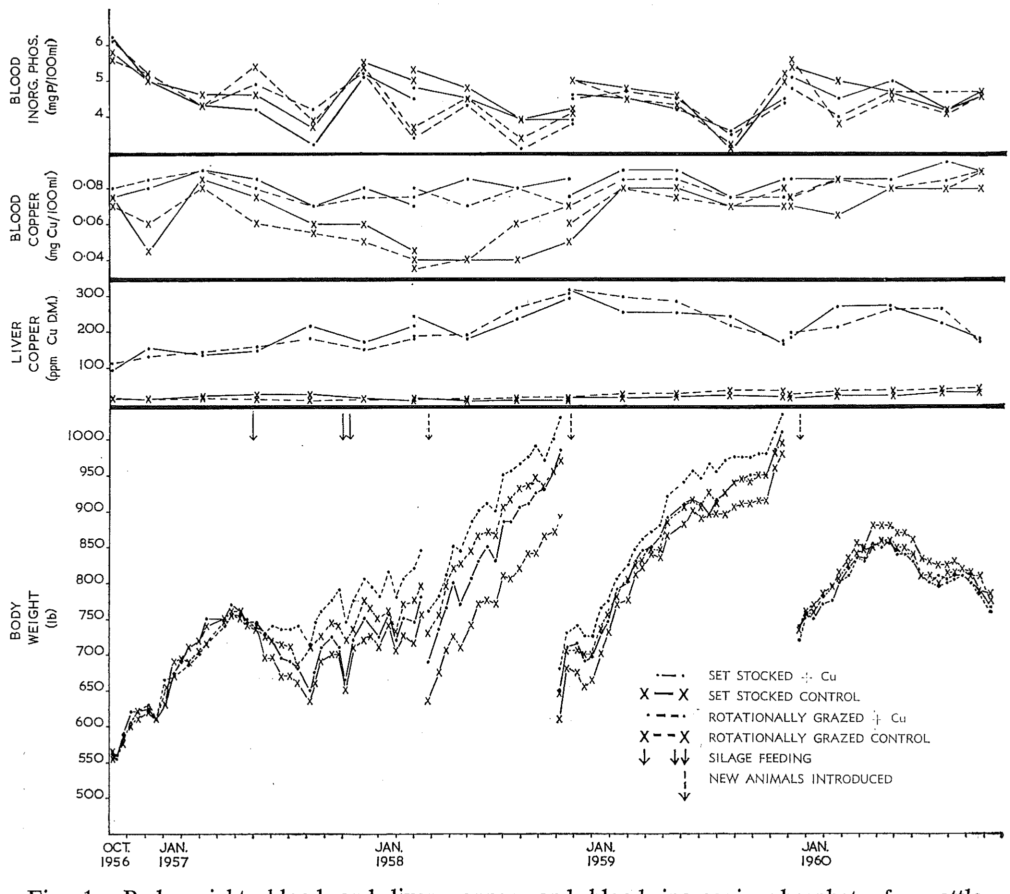

Fig. 1.—Body-weight, blood and liver copper, and blood inorganic phosphate for cattle in each treatment.

TABLE 1

LINEAR GROWTH RATES OF EXPERIMENTAL CATTLE

(lb per Week)

Period	Set Stocked		Rotationally Grazed		S.E. of Group Mean
	S	Sc	R	Rc	
4.xi.56–18.i.57	0·97	0·90	0·94	1·09	±0·07
18.i.57–23.v.57	0·56	0·63	0·64	0·70	±0·07
23.v.57–5.ix.57*	−0·76	−0·90	−0·42	−0·21	±0·07
5.ix.57–19·xii·57	0·63	0·67	0·61	0·60	±0·06
19.xii.57–13.iii.58†	0·21	0·34	0·40	0·56	±0·07
13.iii.58–23.x.58	1·03	1·17	1·07	1·11	±0·06
6.xi.58–26·ii·59	1·31	1·14	1·17	1·10	±0·09
26.ii.59–19.xi.59	0·56	0·61	0·63	0·66	±0·06
17.xii.59–16.vi.60	0·81	0·69	0·69	0·70	±0·04
16.vi.60–10.xi.60	−0·50	−0·36	−0·31	−0·39	±0·07

* During this period animals on set stocking lost weight at a significantly greater rate ($P<0 \cdot 01$).

† During this period animals on rotational grazing gained weight at a significantly greater rate ($P<0 \cdot 05$) and the growth response to copper was significant ($P<0 \cdot 05$).

TABLE 2

MEAN BODYWEIGHT (lb) IMMEDIATELY PRIOR TO CHANGES IN EXPERIMENTAL ANIMALS

Date	Set Stocked		Rotationally Grazed		S.E. of Group Mean
	S	Sc	R	Rc	
13.iii.58*	754	781	797	843	±17
23.x.58*	871	954	957	997	±26
19.xi.59	981	1,009	994	1,034	±51
10.xi.60	785	764	773	760	±17

* At these dates the effects of rotational grazing and of copper therapy were significant ($P<0 \cdot 05$).

From October 1956 to April 1957 all animals gained weight at the rate of approximately 1 lb per head per day and there were no marked differences between groups. Following the harvesting and ensiling of pasture from the rotationally grazed paddocks in February 1957, there was a check in growth in animals in the rotationally grazed groups, but thereafter they continued to gain weight at the same rate as those in the set-stocked treatment. All animals lost weight from April to September 1957. This weight loss was significantly less ($P < 0 \cdot 01$) in groups R and Rc, which were fed the silage conserved from the rotationally grazed paddocks.

In the second year of the experiment all groups gained weight. Over the period from December 1957 to March 1958, the rotationally grazed animals significantly ($P<0\cdot05$) outgrew those on set stocking and there was a significant ($P<0\cdot05$) growth response to copper. By March 1958, the feed available in all paddocks was considered inadequate and the older animals from each treatment were withdrawn. At the reduced stocking rate all animals continued to gain weight, the rate being approximately 1 lb per head per day.

In November 1958, the initial stocking rate of 8 animals per treatment was restored. Throughout the third year of the experiment all animals gained in body-weight, weight changes being of the order of 1·5 lb per head per day in summer and 0·5 lb per head per day in winter and early spring.

In December 1959, the original animals in each treatment were replaced. Good weight gains of approximately 2 lb per head per day occurred in animals from all groups in summer. However, from April until the termination of the experiment in October 1960, body-weight losses were of the order of 0·5 lb per head per day. There were no differences between treatments during the fourth year of the study.

The spot analyses (Table 2) show that both the rotational grazing treatment and the copper therapy had a significant ($P<0\cdot05$) effect on body-weight at the March and October weighings in 1958. The general conclusion appears to be that a treatment effect occurred in the late winter of 1957 and the advantage gained persisted, so groups retained their relative positions while these particular animals were present in the groups.

Blood and Liver Copper Levels.—The mean changes in the level of copper in blood and liver of cattle in each group are shown in Figure 1.

In Groups S and R, which did not receive copper therapy, blood copper levels ranged from 0·04 to 0·09 mg Cu per 100 ml and liver copper levels from 5 to 45 p.p.m. Cu on dry matter. During the period from June 1957 to November 1958, all levels in untreated animals were consistently low, mean blood values ranging from 0·04 to 0·06 mg Cu per 100 ml, and mean liver values from 8 to 20 p.p.m. Cu on dry matter. From February 1959 to the conclusion of the experiment in October 1960, the mean level in blood was satisfactory, ranging from 0·07 to 0·09 mg Cu per 100 ml, and liver copper values showed a gradual increase to 45 p.p.m. Cu on dry matter.

In Groups Sc and Rc, intravenous copper therapy at 3-monthly intervals maintained adequate liver copper reserves ranging from 100 to 300 p.p.m. on dry matter. Blood copper levels in these groups varied from 0·07 to 0·09 mg Cu per 100 ml.

Relationships between blood and liver copper were examined in the untreated Groups S and R. With the relatively small numbers of animals involved, none of the correlations attained significance. Some trends are evident. When liver copper levels were below approximately 20 units, there was a positive correlation between blood and liver copper levels. Very low levels in one were associated with very low levels of the other. As the mean liver copper increased above 20 units the mean blood copper remained at about 0·08 units.

Inorganic Phosphate, Packed Cell Volume and Haemoglobin in Blood.—Levels for inorganic phosphate in blood (Figure 1) ranged from 3·1 to 6·2 mg P per 100 ml. Only at one sampling period (August 1959) were the mean levels in all groups below 4·0 mg P per 100 ml. No consistent differences were apparent between groups.

Packed cell volume ranged from 30 to 40 per cent. and haemoglobin levels varied from 11·5 to 16·0 g per 100 ml. No consistent differences were apparent between groups.

Grazing Behaviour.—The data for grazing behaviour are shown in Figure 2. The times spent grazing by the rotational and set-stocked groups during each 24-hr observation period are summarized in Table 3. The system of grazing management had little influence on grazing behaviour except at the recording period in July 1957, when the rotational group was receiving a silage supplement. This markedly reduced the hours per day spent grazing. From all data the time spent grazing varies widely and does not appear to be related to the quantity and quality of available pasture.

Botanical Composition of Pasture.—Table 4 records line transect data taken in October 1956 and in July 1960. The 1956 measurements were made at the commencement of the study and show a similar botanical composition for both grazing areas. Paspalum was the dominant species but green couch and white clover were both present in significant amounts. The 1960 measurements were made in midwinter near the conclusion of the experiment. There were no marked differences between the two grazing areas, indicating that botanical composition had not been significantly affected by the grazing management systems which had been in use for nearly four years. The dominant pasture species was still paspalum, but as in all winters in this area green couch was making a major contribution to the available pasture. White clover was virtually absent at this season.

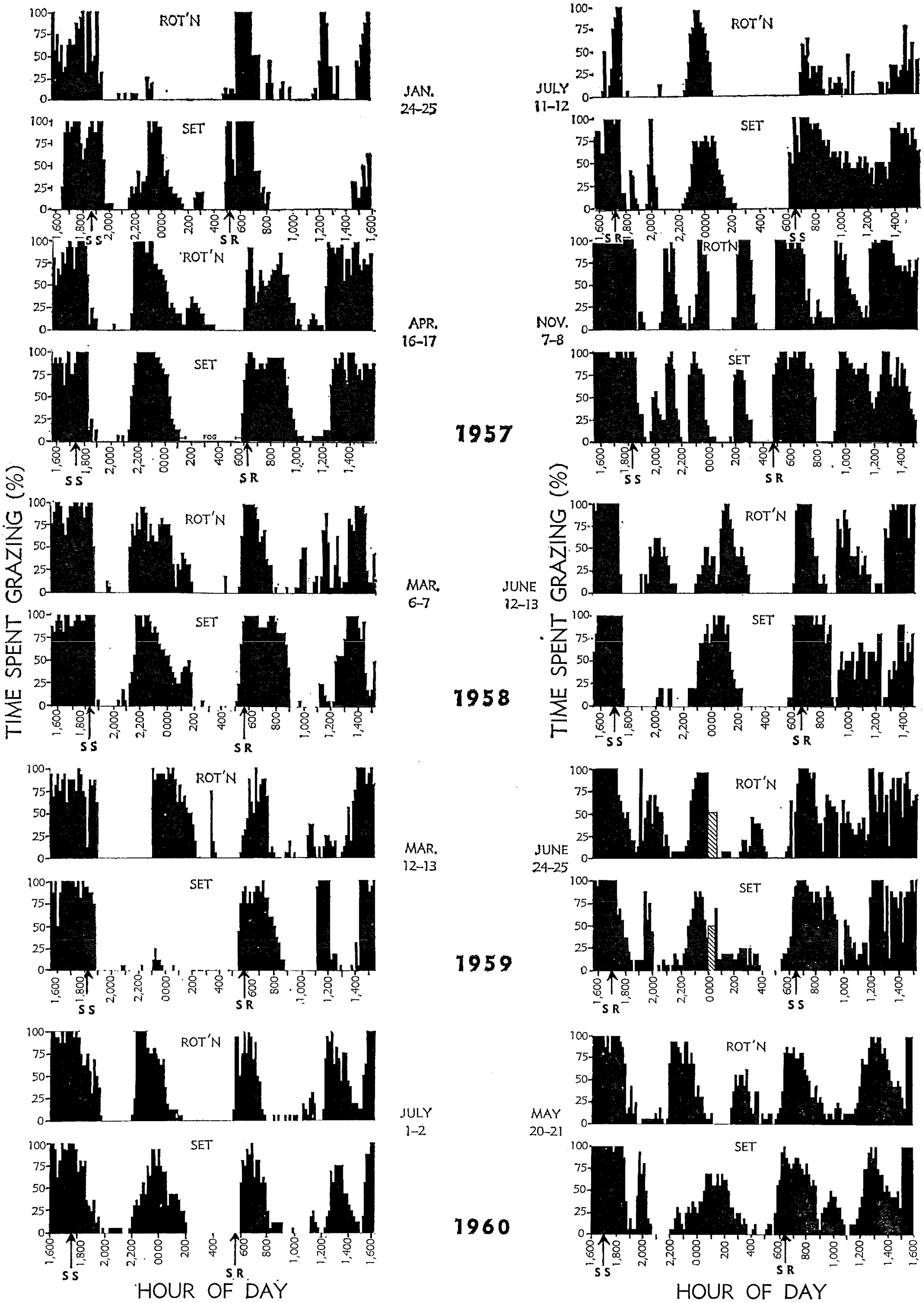

Fig. 2.—Time spent grazing by the set-stocked and rotationally grazed groups during each 24-hr observation period.
(Sunrise **SR**; sunset **SS**.)

TABLE 3

TIME SPENT GRAZING

Date	Percentage of Day Spent Grazing						Night Grazing as Percentage Total Grazing		Hours per Day Spent Grazing	
	Set Stocked			Rotationally Grazed						
	Day	Night*	Total	Day	Night*	Total	Set	Rotational	Set	Rotational
24–25.i.57	22·1	7·5	29·6	21·9	1·1	23·0	25·2	4·3	7·10	5·52
16–17.iv.57	31·9	10·8	42·7	30·2	11·6	41·8	25·3	27·7	10·25	10·03
11–12.vii.57	23·4	9·6	33·0	10·1	4·9	15·0	29·1	32·7	7·92	3·60
7–8.xi.57	41·5	12·5	54·0	31·4	12·2	43·6	23·2	28·0	12·96	10·46
6–7.iii.58	33·1	12·3	45·4	29·4	11·5	40·9	27·1	28·1	10·89	9·82
12–13.vi.58	26·6	10·4	37·0	29·4	11·5	40·9	28·1	28·1	8·88	9·82
12–13.iii.59	30·8	0·6	31·4	18·4	11·2	29·6	1·9	37·8	7·54	7·10
24–25.vi.59	33·5	9·9	43·4	32·0	11·6	43·6	22·8	26·6	10·42	10·46
1–2.iv.60	24·9	9·1	34·0	27·8	8·7	36·5	26·8	23·8	8·16	8·76
20–21.v.60	39·5	9·1	48·6	30·8	12·6	43·4	18·7	29·0	11·52	10·41

* The hours of darkness from approximately 30 min. after sunset to 30 min. before sunrise.

TABLE 4

MEAN POPULATION OF BOTANICAL SPECIES IN EACH GRAZING SYSTEM

Species	Mean Population (%)			
	Set-stocked Area		Rotationally Grazed Area	
	16.x.56	29.vii.60	16.x.56	29.vii.60
Paspalum (*Paspalum dilatatum*)	52·5	57·5	48·7	52·2
Green couch (*Cynodon dactylon*) ..	11·4	15·6	22·9	24·2
Queensland blue couch (*Digitaria didactyla*)	5·4	12·5	2·5	9·4
White Clover (*Trifolium repens*)	14·4	3·2	17·8	3·8
Miscellaneous pasture and weed species ..	16·3	11·2	8·1	10·4

Pasture Yields.—The pasture production is shown in Table 5 and Figure 3. The initial measurements at the commencement of the experiment in October 1956 tend to indicate a higher yield in the set-stocked area. In the first year of the experiment the maximum yield was in the rotationally grazed paddocks in

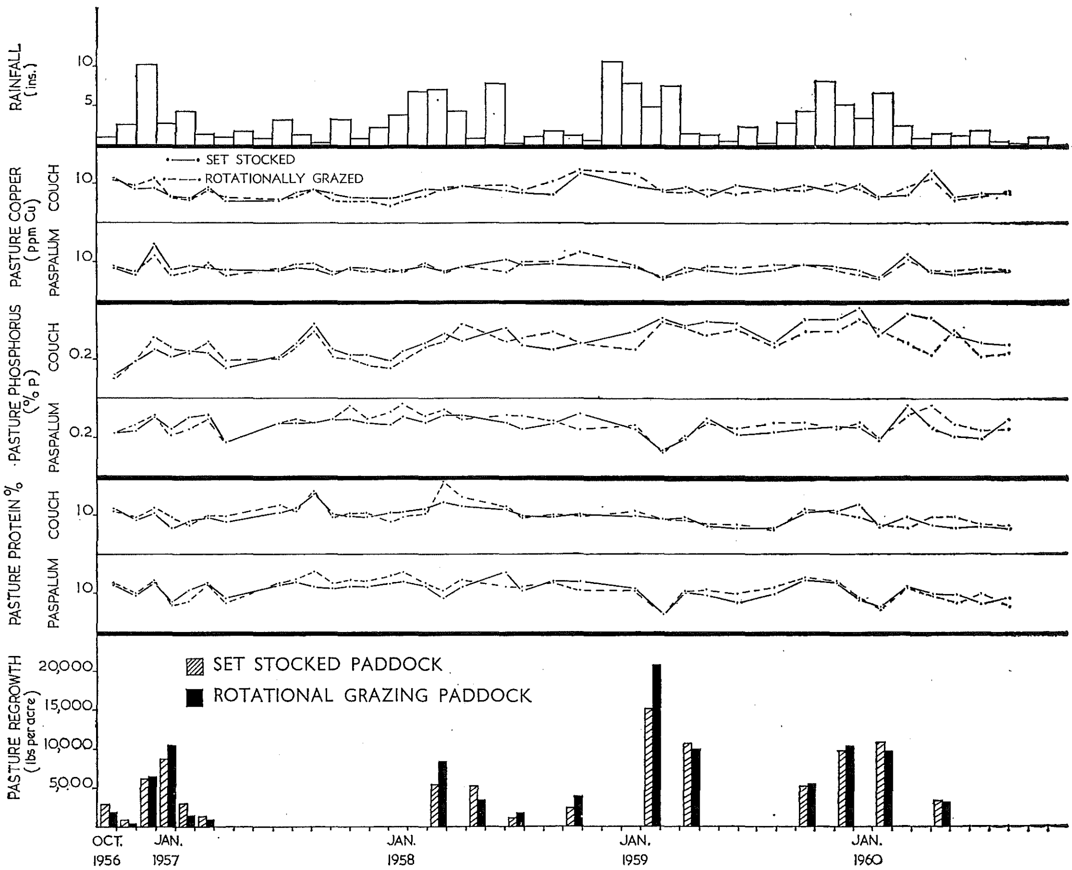

Fig. 3.—Rainfall and dry-matter yield and chemical composition of regrowth pasture from set-stocked and rotationally grazed paddocks.

January 1957. These paddocks were mown in February and the pasture conserved as silage. The succeeding yield measurements in February and March showed lower pasture yields in this area than in the unmown set-stocked area. Regrowth during the first year of this experiment was comparable under both grazing systems in spite of an apparent check in growth following pasture conservation in the rotationally grazed paddocks in February. Due to adverse seasonal conditions, no measurable regrowth could be recorded during the period March 1957 to March 1958.

TABLE 5

PASTURE PRODUCTION IN EACH GRAZING SYSTEM

Period of Regrowth	Forage per Acre (lb Green Weight)	
	Set-stocked Area	Rotationally Grazed Area
Commencement	2,954	1,786
29.x.56–29.xi.56..	880	392
29.xi.56–27.xii.56	6,290	6,403
27.xii.56–24.i.57	8,607	10,454
24.i.57–21.ii.57	2,910	1,481
21.ii.57–21.iii.57	1,446	828
21.iii.57–25.-x.57	Not measurable	Not measurable
First Year of Experiment ..	20,133	19,558
25.x.57–25.iii.58	5,471	8,233
25.iii.58–6.v.58	5,088	3,485
6.v.58–11.vii.58	1,133	1,568
11.vii.58–27.x.58	2,405	3,833
Second Year of Experiment	14,097	17,119
27.x.58–4.ii.59	15,002	20,560
4.ii.59–30.iv.59	10,524	9,975
30.iv.59–28.x.59..	5,053	5,314
Third Year of Experiment ..	30,579	35,849
28.x.59–11.xii.59	9,618	10,280
11.xii.59–12.ii.60	10,681	9,583
12.ii.60–10.v.60	3,311	3,020
10.v.60–20.x.60	Not measurable	Not measurable
Fourth Year of Experiment	23,610	22,883
Total	88,419	95,409

The second year of the experiment was a drought year. Although yield tended to be higher in the rotationally grazed area, total pasture production was low under both grazing systems. No conservation of pasture was possible in this year.

Pasture production was highest during the third year of the study. The yield was greatest in the rotationally grazed area. No pasture conservation was practised as the objective in this year was to compare the two grazing systems without this added variable. Yield measurements indicated that approximately twice the amount of silage conserved in 1957 could have been conserved early in February 1959 from the rotationally grazed area. Moderate pasture production was evident in both areas in the summer of 1959-60 in the fourth year of the study. Pasture conservation could have been undertaken in the rotationally grazed paddocks in December 1959. However, by February 1960 both the quantity and the quality of pasture had deteriorated and conservation was not attempted. The total regrowth of pasture during the 4-year study was greater in the rotationally grazed paddocks than in the set-stocked area.

Chemical Composition of the Pasture.—The protein, phosphorus and copper levels in regrowth samples of the three main pasture species from each grazing treatment are shown in Table 6 and Figure 3. White clover was not present from November 1956 to April 1958 and again from May to October in 1960. During the summer of 1958-59 and the summer of 1959-60 the amount of white clover available was sufficient for analysis but was too small to make any marked contribution to the animals' diet. The amount of regrowth paspalum and green couch during the period March 1957 to March 1958 was insufficient for yield measurements although adequate for sampling for chemical analysis.

Neither system of grazing management had a marked influence on the chemical composition of the main pasture species as assessed by the analyses of these regrowth samples. In all four years the protein level in paspalum tended to be lowest in late summer, i.e. February to March. The protein concentration in green couch was similar to that of paspalum. The protein level in white clover was high, ranging from 18 to 25 per cent. on a dry-matter basis.

In all pasture species the phosphorus level was satisfactory for cattle provided feed intake was adequate.

Copper levels were similar in all pasture species. The levels in these regrowth samples showed no obvious seasonal trends and the range was from 5 to 15 p.p.m. Cu on dry matter. Molybdenum levels were low, ranging from less than 0·1 to 0·6 p.p.m. Mo on dry matter. Inorganic sulphate levels were appreciable, ranging from 0·1 to 0·75 per cent. on a dry-matter basis.

TABLE 6

CHEMICAL COMPOSITION OF REGROWTH PASTURE ON DRY-MATTER BASIS

Date	Protein (%)						Phosphorus (%)						Copper (p.p.m. Cu)					
	Paspalum		Green Couch		White Clover		Paspalum		Green Couch		White Clover		Paspalum		Green Couch		White Clover	
	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†
25.x.56	12·0	12·4	11·5	11·0	18·9	18·5	0·22	0·32	0·12	0·10	0·25	0·26	8·2	8·4	11·5	11·0	9·3	9·0
29.xi.56	9·1	10·0	8·6	9·3	Absent		0·23	0·26	0·19	0·19	Absent		6·5	7·2	8·6	9·3	Absent	
27.xi.56	12·6	13·1	10·3	11·8	,,		0·30	0·31	0·25	0·31	,,		14·3	11·4	8·8	11·4	,,	
24.i.57	7·8	6·8	6·6	9·3	,,		0·24	0·20	0·21	0·26	,,		7·8	6·4	6·9	6·7	,,	
21.ii.57	10·7	7·9	8·1	7·4	,,		0·30	0·24	0·24	0·23	,,		8·8	7·1	6·2	5·8	,,	
21.iii.57	12·5	12·4	9·1	9·6	,,		0·31	0·29	0·23	0·29	,,		8·2	9·3	9·0	8·4	,,	
18.iv.57	8·6	7·3	8·0	9·6	,,		0·17	0·17	0·15	0·19	,,		7·8	6·1	5·3	6·4	,,	
11.vii.57	12·0	12·3	10·4	12·4	,,		0·27	0·27	0·21	0·20	,,		7·7	7·8	5·4	5·8	,,	
6.viii.57	12·9	13·6	11·8	10·8	,,		0·27	0·29	0·28	0·26	,,		8·1	9·2	7·6	6·4	,,	
5.ix.57	11·6	15·3	15·2	16·0	,,		0·27	0·27	0·38	0·34	,,		7·8	9·5	8·4	8·4	,,	
3.x.57	11·0	12·4	10·2	9·3	,,		0·29	0·29	0·25	0·21	,,		6·5	7·3	7·5	5·6	,,	
31.x.57	11·7	13·2	9·7	10·5	,,		0·29	0·36	0·22	0·20	,,		8·4	8·1	6·4	5·2	,,	
28.xi.57	11·5	13·0	9·3	10·5	,,		0·27	0·29	0·22	0·17	,,		8·1	7·2	6·3	5·2	,,	
3.i.58	12·2	14·2	10·5	8·0	,,		0·26	0·33	0·19	0·15	,,		7·1	8·0	6·2	4·3	,,	
23.i.58	12·9	15·2	10·5	9·1	,,		0·30	0·37	0·24	0·19	,,		7·6	7·1	6·7	5·4	,,	
26.ii.58	11·5	12·3	11·4	10·2	,,		0·27	0·31	0·28	0·26	,,		8·8	9·3	8·5	6·8	,,	
25.iii.58	8·6	10·6	13·1	18·6	,,		0·31	0·34	0·33	0·29	,,		7·3	7·2	8·2	8·7	,,	
26.iv.58	11·8	13·3	12·3	14·8	,,		0·31	0·29	0·29	0·38	,,		8·7	8·7	9·2	9·2	,,	
3.vii.58	15·1	11·8	11·3	12·1	19·9	23·4	0·27	0·31	0·36	0·29	0·41	0·38	0·5	7·2	8·1	9·5	11·9	10·3

* Pasture regrowth samples from set-stocked area.

† Pasture regrowth samples from rotationally grazed area.

TABLE 6—continued

CHEMICAL COMPOSITION OF REGROWTH PASTURE ON DRY-MATTER BASIS—continued

Date	Protein (%)						Phosphorus (%)						Copper (p.p.m. Cu)					
	Paspalum		Green Couch		White Clover		Paspalum		Green Couch		White Clover		Paspalum		Green Couch		White Clover	
	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†	S*	R†
28.vii.58	10·5	11·7	9·9	9·6	23·1	23·3	0·24	0·31	0·27	0·31	0·29	0·37	9·0	9·8	7·8	8·1	10·6	11·9
15.ix.58	13·0	12·6	9·7	10·0	20·3	21·5	0·37	0·28	0·25	0·34	0·26	0·26	9·5	9·9	7·1	10·6	9·7	10·5
27.x.58	12·9	10·9	10·0	9·9	18·5	19·7	0·32	0·24	0·28	0·28	0·32	0·33	..	12·6	12·9	13·4	12·1	19·7
21.i.59	11·0	10·5	9·9	11·0	20·7	22·3	0·24	0·26	0·34	0·25	0·30	0·31	8·6	8·7	9·5	12·4	14·4	16·3
5.iii.59	4·5	4·5	8·9	8·9	18·9	20·5	0·13	0·12	0·41	0·39	0·31	0·32	5·8	5·6	8·2	8·0	9·8	10·3
9.iv.59	10·0	10·1	9·1	8·8	19·7	19·8	0·19	0·20	0·37	0·36	0·32	0·34	8·4	7·3	9·0	7·8	11·4	9·4
12.v.59	9·3	10·8	7·0	7·7	19·2	20·7	0·29	0·27	0·39	0·32	0·25	0·27	7·7	8·6	6·6	8·4	8·7	9·1
29.vi.59	7·3	9·9	6·7	7·4	21·0	21·5	0·21	0·24	0·38	0·35	0·26	0·28	6·7	8·2	6·4	7·1	9·8	9·4
28.viii.59	9·6	11·2	6·6	6·4	22·6	23·1	0·22	0·27	0·28	0·26	0·34	0·33	7·8	9·0	8·0	8·2	10·3	10·8
15.x.59	13·2	13·6	10·5	11·1	18·0	18·9	0·24	0·27	0·40	0·34	0·28	0·32	9·0	9·0	9·5	8·0	9·3	10·4
4.xii.59	12·6	13·0	10·9	10·7	24·2	24·5	0·25	0·24	0·40	0·34	0·34	0·35	8·5	7·8	7·8	10·0	10·1	10·6
8.i.60	8·2	8·5	12·5	9·4	20·3	20·6	0·25	0·27	0·46	0·40	0·29	0·26	7·6	6·4	9·7	8·4	9·8	9·7
12.ii.60	6·1	5·9	6·8	7·3	19·7	19·2	0·18	0·19	0·32	0·35	0·29	0·33	5·7	5·3	6·7	6·6	10·1	9·7
28.iii.60	11·8	11·5	9·3	6·8	20·3	20·3	0·36	0·31	0·43	0·28	0·30	0·31	11·4	10·3	7·0	9·0	8·2	10·5
3.v.60	9·9	9·2	7·3	9·2	Absent		0·24	0·36	0·41	0·22	Absent		7·0	7·3	13·2	11·4	Absent	
10.vi.60	9·5	7·3	6·7	9·3	,,		0·20	0·26	0·32	0·34	,,		6·5	7·1	6·3	5·9	,,	
18.vii.60	7·3	9·9	7·0	7·3	,,		0·19	0·23	0·28	0·21	,,		7·2	8·0	7·1	6·9	,,	
30.viii.60	8·7	6·4	6·7	7·1	,,		0·29	0·24	0·27	0·23	,,		7·2	7·2	7·2	7·4	,,	

* Pasture regrowth samples from set-stocked area.

† Pasture regrowth samples from rotationally grazed area.

Pasture Silage.—The pasture conserved from the four rotationally grazed paddocks in February 1957 was harvested by means of a cutter-bar type commercial harvester. It was ensiled in a concrete tower silo with a capacity of about 70 tons. Approximately 56 tons of pasture was conserved. The proximate analysis was:—

	As Taken from Tower (%)	Dry-matter Basis (%)
Moisture	72·3	—
Crude protein	2·1	7·6
Ether extract	0·6	2·3
Crude fibre	10·2	36·9
Nitrogen-free-extract	12·2	43·9
Ash	2·6	9·3
Calcium (Ca)	0·05	0·16
Phosphorus (P)	0·07	0·26

The results of quality tests on this silage as taken from the tower were as follows: pH 5·0; lactic acid 0·36 per cent.; acetic acid 0·37 per cent.; lactic acid: acetic acid ratio 0·97; total nitrogen 0·34 per cent.; amino acids 0·04 per cent.; and volatile bases nil. These tests indicate only a fair quality product, the pH being too high and the acid content too low for a good quality silage.

Rainfall.—Rainfall data for the four years of the study are shown in Figure 3. In each year maximum monthly rainfall occurred in summer, from December to February, and minimum levels in winter, from July to October.

V. DISCUSSION

In the subtropical environment in which the Animal Husbandry Research Farm is located, the growth of pasture is closely related to the amount and distribution of the essentially summer rainfall. In the summer of 1956-57 good rain fell in early December and resulted in fair growth of pasture by January. This was conserved by harvesting the rotationally grazed paddocks and approximately 56 tons of grass was laid down as silage. Follow-up rains in late summer were limited, resulting in a restricted season of pasture growth. This was particularly evident in the rotationally grazed paddocks which had been mown for silage in February 1957. Animals lost weight from April to September, weight losses being minimized in the rotationally grazed group which were supplemented for six months from June 1957 with grass silage previously conserved for these paddocks.

The 12-month period from March 1957 was virtually a drought year for this environment. This was aggravated by lack of effective summer rains until late January 1958. No pasture conservation was possible, the regrowth yields being negligible. By March 1958 animals in the unsupplemented set stocked group had barely regained body-weight shown in March 1957, and the stocking rate in all groups was reduced from 1 animal per acre to 1 animal per 1·6 acres.

There was a good distribution of rainfall in the late summer and early winter of 1958 and at the reduced stocking rate animals gained weight in winter under both grazing management systems.

The third year of this experiment was the most productive, as shown by animal weight gains and pasture production. There were good rains in December 1958 and good follow-up rains in January, February and March 1959. The maximum pasture yield was recorded in the rotationally grazed paddock in February. Only the experimental programme in this year of a direct comparison of the two grazing treatments without added variables prevented pasture conservation. There were good rains also in September and in each month thereafter until February 1960.

In the fourth year of the experiment the good spring rains resulted in early pasture growth. By February this pasture had deteriorated both in quality and in quantity and would have been unsuitable for conservation as silage. At this stage the protein level was 5·9 per cent. in paspalum and 7·3 per cent. in green couch and the amount of white clover present was negligible. All animals lost weight in the winter of 1960.

It was only during the winter of 1957, when the pasture silage conserved from the rotationally grazed paddocks was fed back, that differences in body-weight were apparent in favour of the rotationally grazed groups. This response was maintained throughout the second year of the experiment. In the productive third year of the experiment, animals gained weight even in winter and there were no marked differences between grazing treatments. Approximately twice the amount of silage conserved in 1957 could have been made in January/February 1959. In the fourth year of the experiment there were again no marked differences between grazing treatments and in the absence of pasture conservation and winter supplementation all groups showed a marked loss in weight during winter.

The grazing behaviour observations indicate that, apart from the period of supplementation, the amount of time spent grazing and the daily pattern of grazing were similar for cattle under each grazing system. This is in agreement with the findings of Sheppard, Blaser, and Kincaid (1957). Under our experimental conditions the time spent grazing was largely independent of the influence of season on the quantity and quality of pasture. This is contrary to the findings of Hancock (1950) and Halley (1951). The former showed an inverse correlation between grazing time and fibre content when ample pasture was available; the latter found that for a particular pasture quality, grazing time was inversely related to quantity of available pasture.

Sunrise and sunset had a marked effect on grazing behaviour. The morning grazing period commenced about 30 min before sunrise and the afternoon grazing ceased from 30 to 60 min after sunset. This effect has been reported by Hughes and Reid (1951). Under our experimental conditions approximately 20–30 per cent. of the grazing was done at night. This is of the same order as that reported for native cattle in Rhodesia (Smith 1959) but is markedly lower than the 67 per cent. night grazing by Friesian cows in Fiji (Payne, Laing, and Raivoka 1951). This suggests that the Hereford cattle used in our experiment were adapted to their environment.

The pasture-animal growth data for the four years indicates four considerations in relation to grazing management:—

(1) At a stocking intensity of one animal per acre the productivity of continuously grazed paspalum–green couch pasture in this environment is not increased by the application of rotational grazing management.

(2) Rotational grazing management facilitates the shutting up of paddocks in favourable seasons so that pasture conservation may be undertaken.

(3) In this environment pasture conservation should be restricted to those years in which effective rainfall occurs in December or early January. This permits harvesting in late January or early February and allows a greater safety factor in ensuring adequate pasture regrowth before winter.

(4) The feeding back of conserved pasture silage in late winter increases productivity of beef cattle in this environment.

Our findings are not in agreement with those recorded for Hereford cattle grazing native pastures in the Gayndah district of south-eastern Queensland (Anon. 1960, p. 35), where weight gains in 1959-60 were greater under set stocking than under rotational grazing. Essential experimental differences were the low stocking rate of 1 animal to 6 acres and the predominantly spear grass (*Heteropogon contortus*) pasture in the latter experiment. Blaser *et al.* (1959) and Smoliak (1960) have attributed higher productivity in cattle at a moderate intensity of stocking on continuously grazed pastures to more selective grazing under this system of management. On the other hand, Campling, McLusky, and Holmes (1958) and Logan and Miles (1958) have shown a productive response in favour of animals which are rotationally grazed. This response has been related either to a variation in stocking intensity in favourable seasons or to a continuously high stocking rate such that a variable level of supplementary feeding is necessary to give the same optimum level of production. It is evident from the findings of McMeekan (1960) that the greater efficiency of the more intensive system of grazing management can only be exploited fully by pasture conservation and/or high stocking rates. In the environment in which our studies were made an increased stocking rate in summer is not likely to be practised on a commercial scale. On the other hand, it is evident that in at least two of the four years of this study the conservation of excess summer pasture to give a good reserve of fair quality silage could have been practised under a rotational grazing management system. It is evident also that a silage supplement of this quality can be used to prevent weight losses in adverse winters.

The superimposing of a copper supplementation treatment on each grazing management system was based on previous experience in this locality. A low copper status in grazing cattle at the Animal Husbandry Research Farm has been reported by Sutherland (1956), Harvey *et al.* (1961) and Ryley *et al.* (1961). This is again apparent from the low liver copper levels in animals from the untreated groups throughout the four years of this study. It is evident also from the low blood copper status in untreated animals particularly during the period June 1957 to November 1958.

There is no indication that the system of grazing management had any marked influence on the copper status of the experimental cattle. Similarly there were no marked differences in the copper content of pasture from each grazing area. The copper concentration in paspalum ranged from 5 to 14 p.p.m. on dry matter and was usually in excess of 7 p.p.m. Similar levels were found in green couch. The copper content of white clover usually exceeded that of paspalum and green couch. In all pasture species on this property there is no evidence of a consistent seasonal pattern in relation to copper content.

The analytical data indicate that the low copper status in grazing cattle on this property is not due to a low copper status in pasture. As the molybdenum levels are low in all pasture species, this element would not appear to be involved as the factor interfering with the metabolism of copper by cattle in this locality. Some other interference factor, at present unknown, must therefore be suspected. These findings are in agreement with those of Harvey *et al.* (1961) and Ryley *et al.* (1961).

There is some evidence of a growth response to copper therapy in animals from both grazing management systems during the period from June 1957 to October 1958. This corresponds to the only prolonged period in this 4-year study when blood copper levels in untreated groups were consistently low, mean levels ranging from 0·04 to 0·06 mg Cu per 100 ml blood. During the fourth year of the study the blood copper levels in untreated cattle did not fall below 0·07 mg Cu per 100 ml and there was no indication of a response to copper therapy. From May 1959 until the conclusion of the study in October 1960, liver copper levels tended to increase in unsupplemented animals from both grazing management systems.

The findings from the copper supplementation treatments suggest four considerations related to the low-copper status in grazing cattle on this property:—

(1) The low liver-copper reserves in cattle are due to the presence of some factor in pasture which interferes with the ability of the animal to metabolize and store copper. This factor is not molybdenum in the presence of inorganic sulphate.

(2) There is a positive correlation between blood and liver copper values when the liver-copper level is low. However, blood copper levels may lie within the normal range in spite of moderately low values for liver copper.

(3) A body-weight response to copper therapy would appear to be related to the period when blood-copper levels are low.

(4) Some form of copper therapy is desirable for cattle in this locality. Without supplementation, liver-copper reserves remain low and in some seasons may be inadequate to ensure optimum growth.

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